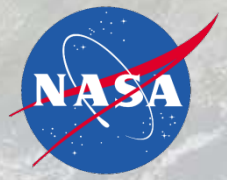


Observations During GRIP From HIRAD: Images of C-Band Brightness Temperatures and Ocean Surface Wind Speed and Rain Rate

T. L. Miller[1], M. W. James[1], **J. Brent Roberts**[1], L. Jones[2], C. S. Ruf[3], E. W. Uhlhorn[4], S. Biswas[2], C. May[2], P. G. Black[5], and C. D. Buckley[6]

[1]NASA/Marshall Space Flight Center, Huntsville, AL

[2]University of Central Florida, Orlando

[3]University of Michigan, Ann Arbor

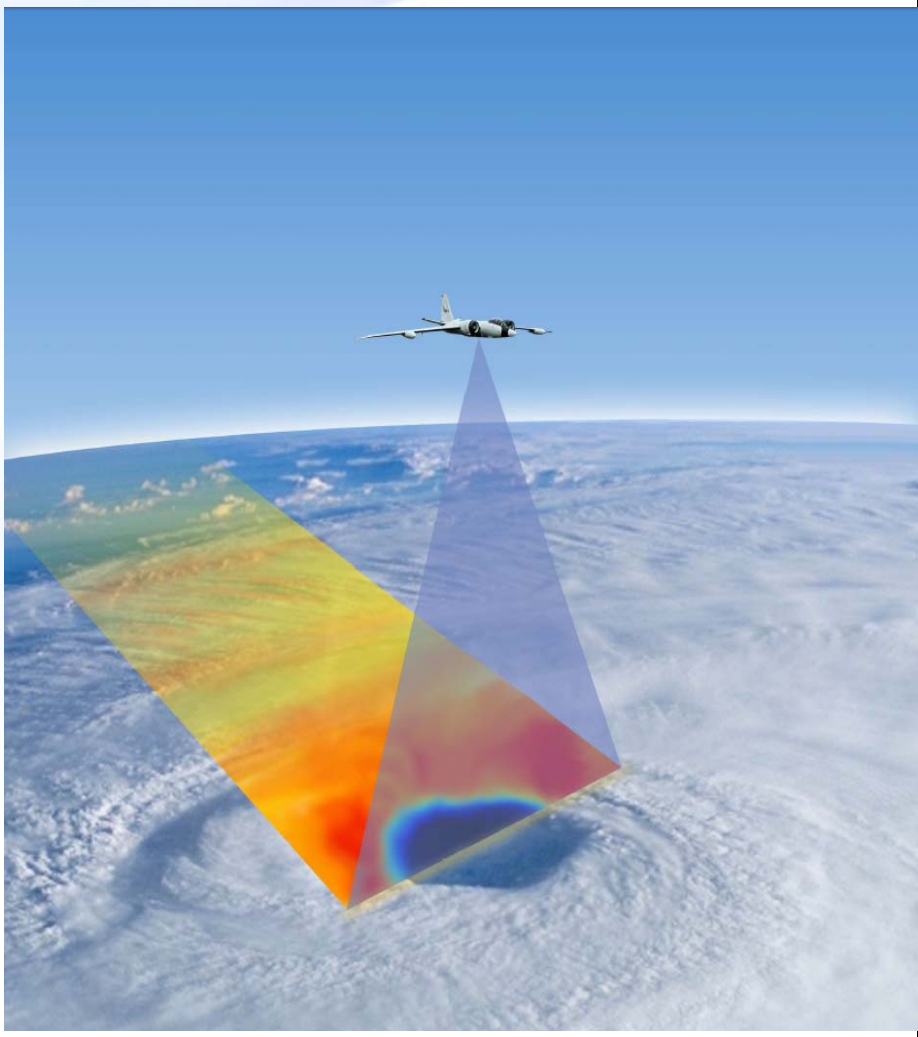
[4]NOAA/AOML/Hurricane Research Division, Miami, FL

[5]SAIC/Naval Research Laboratory, Monterey, CA

[6]Universities Space Research Association, NASA/MSFC

Hurricane Imaging Radiometer (HIRAD)

- Passive microwave (C-band, 4 – 6.6 GHz) radiometer to infer wind speed and rain rate over ocean surface
- HIRAD's unique contribution: Swath measurement of rain rate and hurricane-strength winds, even through heavy rain
  - Wind speed ~10 – 85 m/s
  - Rain rate ~ 5 – 100 mm/hr
- Operations: Improved definition of maximum wind speed and vortex structure
- Science hypothesis: Understanding of TC processes and short-term forecasts of intensity and structure will be improved by assimilation of HIRAD data

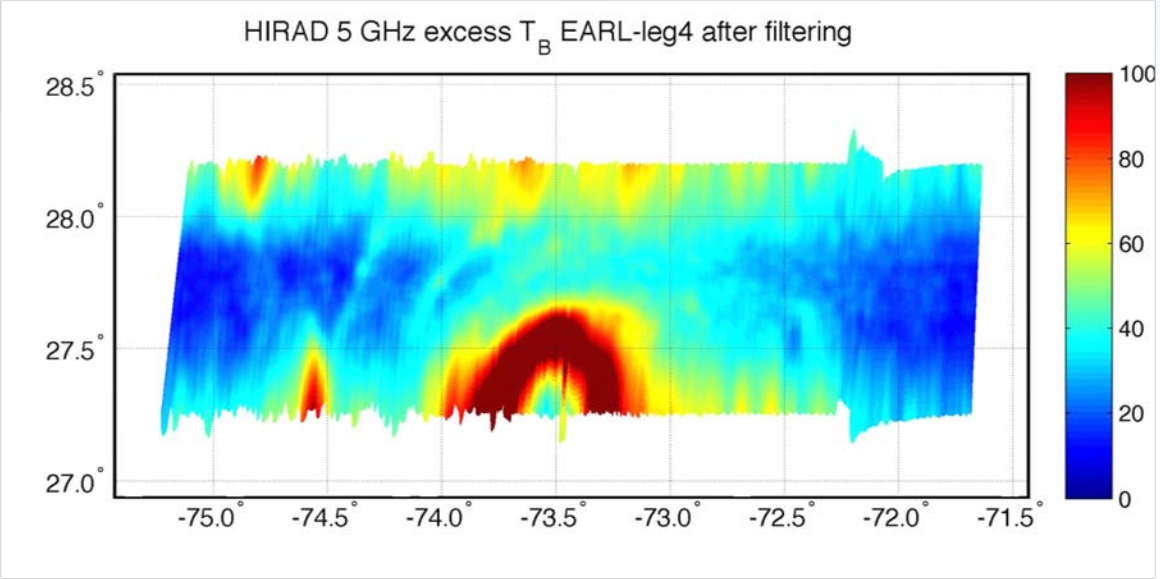


Principle of Operation

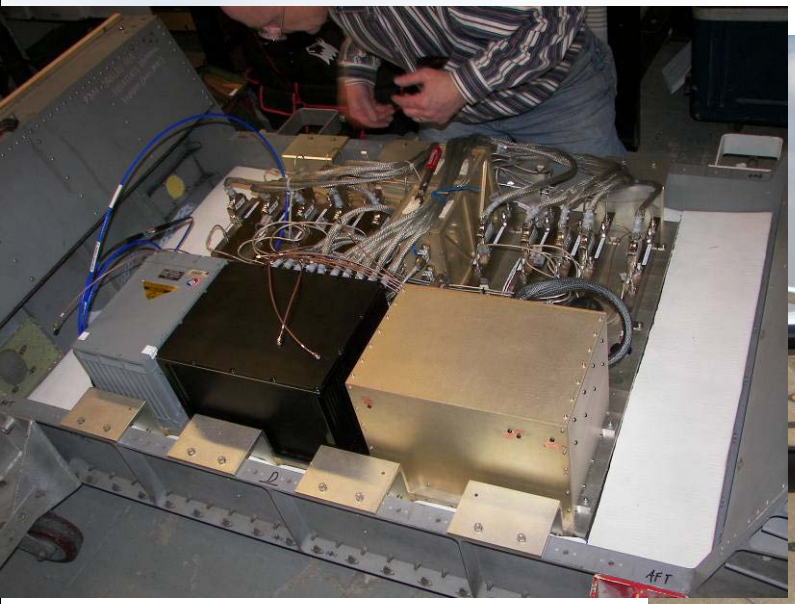
- Matter emits electromagnetic radiation in a broad range of wavelengths or frequencies
- The frequency range includes what is referred to as “C-Band,” or 4 – 8 GHz
- The strength of the emission depends upon many factors, especially temperature
- The other major factor is “emissivity,” which for the ocean surface is affected by the amount of foam and salinity
- The strength of the C-band emission is a known function of wind speed over the ocean surface. This has been verified by experiment and many hours of measurement.
- The other major factor that determines the radiation that HIRAD senses is the amount of rainwater in the atmosphere. Rainwater also emits C-band radiation.

HIRAD's Heritage

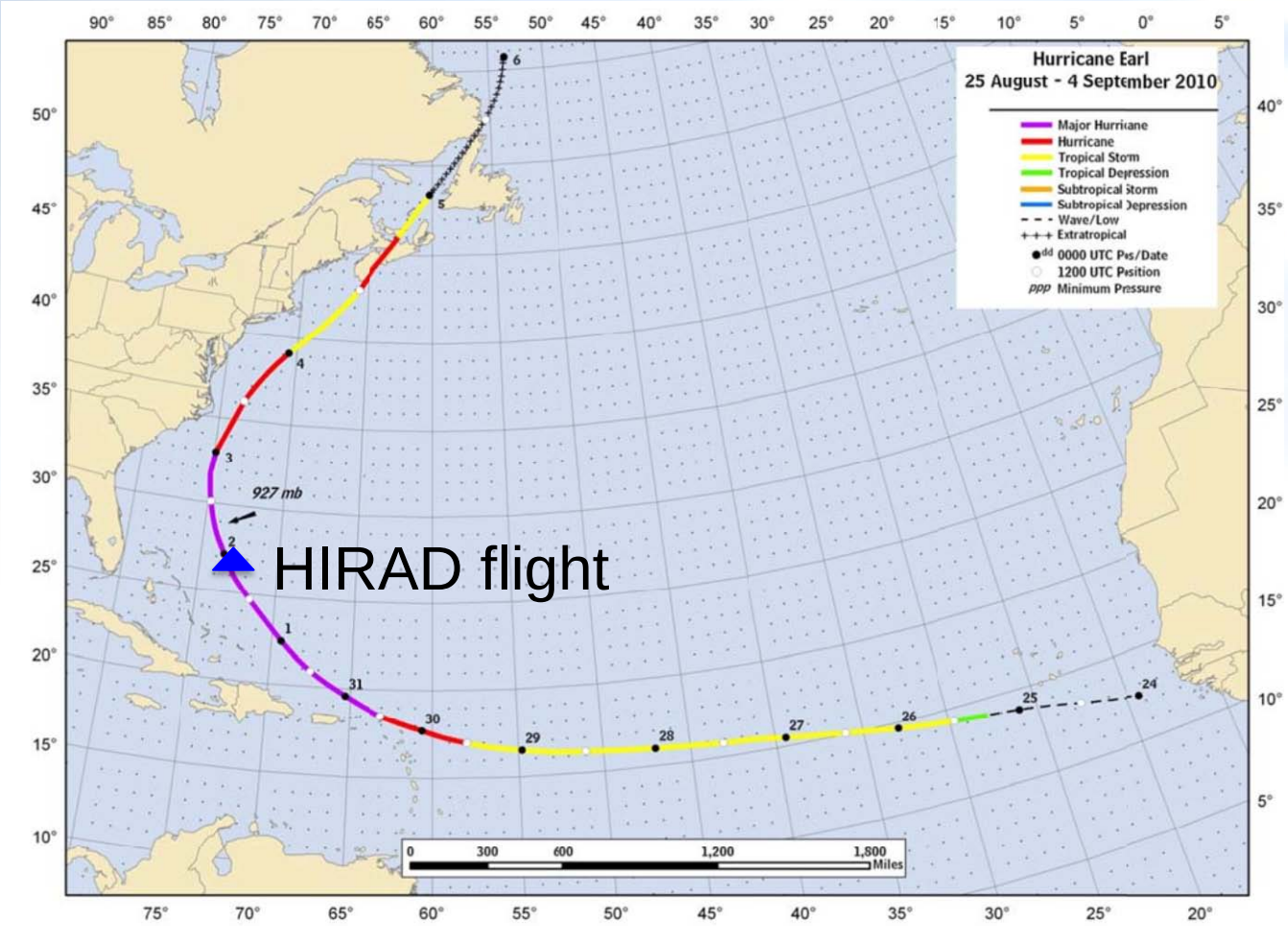
- Currently, NOAA and the USAF use an instrument on the hurricane-surveillance aircraft that measures ocean surface wind speed using the same technique as HIRAD.
- HIRAD's new contribution is that it obtains a swath of measurements, rather than a single line under the aircraft.
- Both of these instruments use multiple frequencies in the C-band to retrieve both wind speed and rainwater



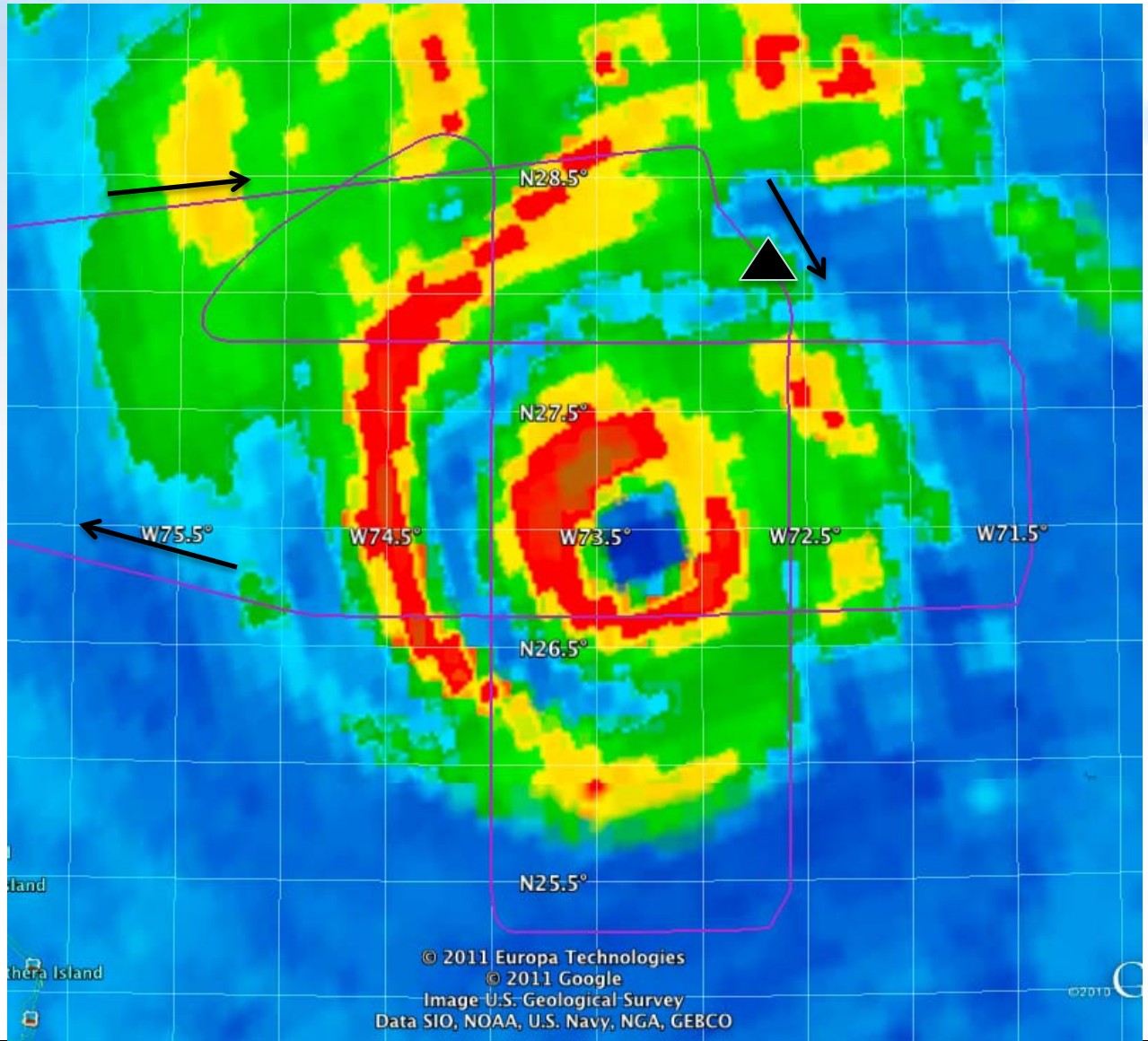
HIRAD integration on WB-57



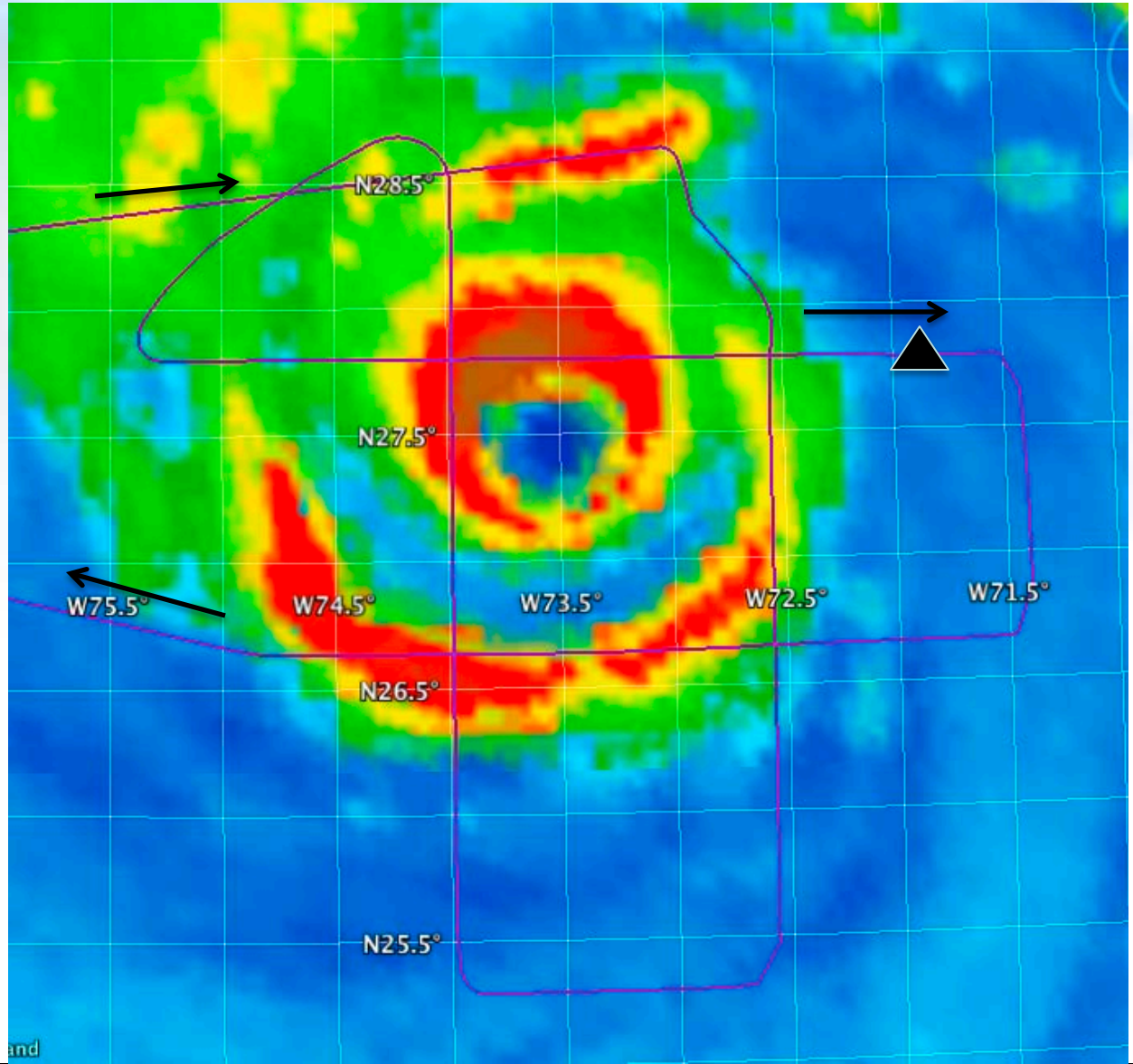
Hurricane Earl



Earl, 2320 UTC, in 85GHz (SSMIS F16)
Triangle indicates WB-57/HIRAD position

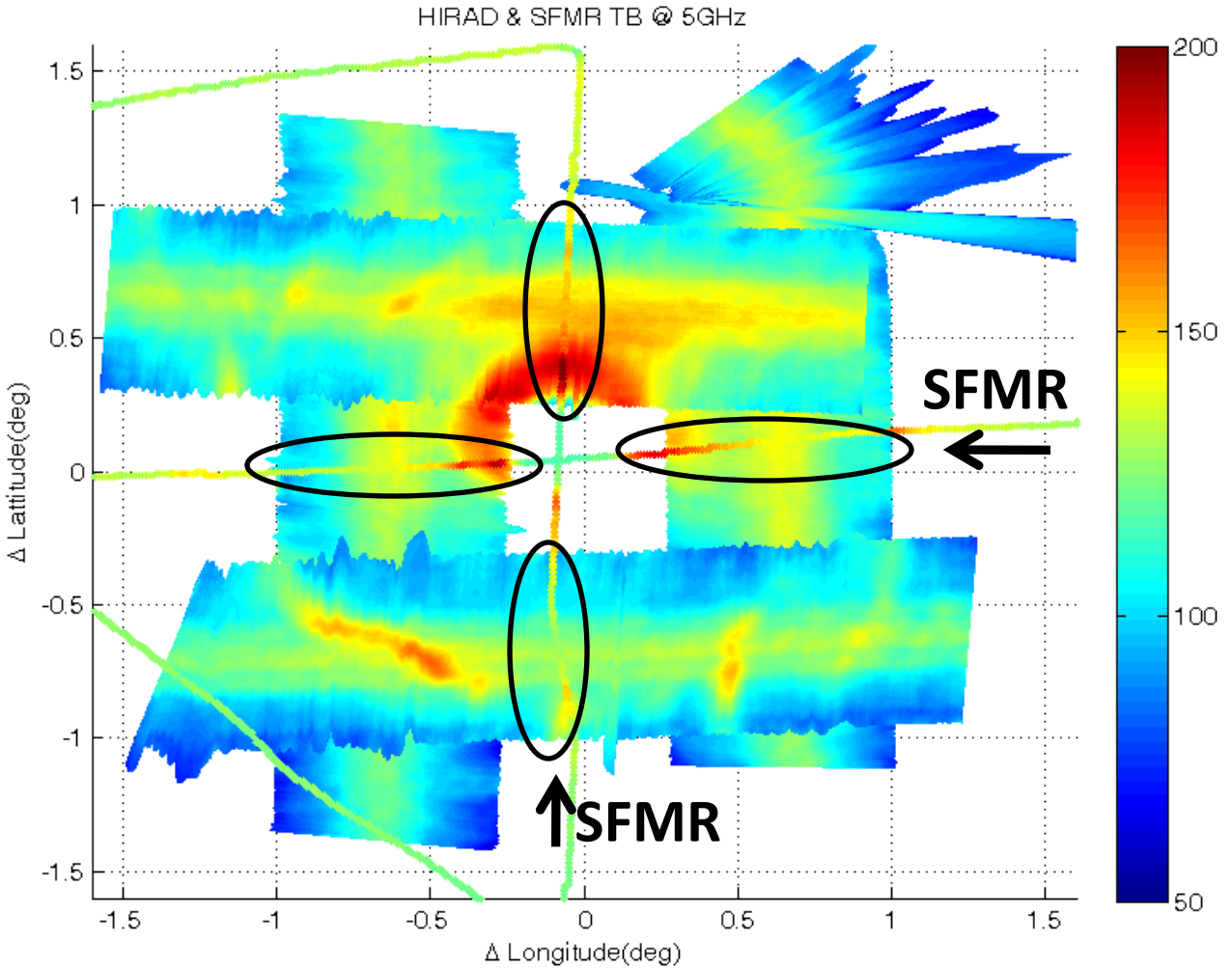


Earl, 0059 UTC, in 85GHz (SSMIS F18)
Triangle indicates WB-57/HIRAD position



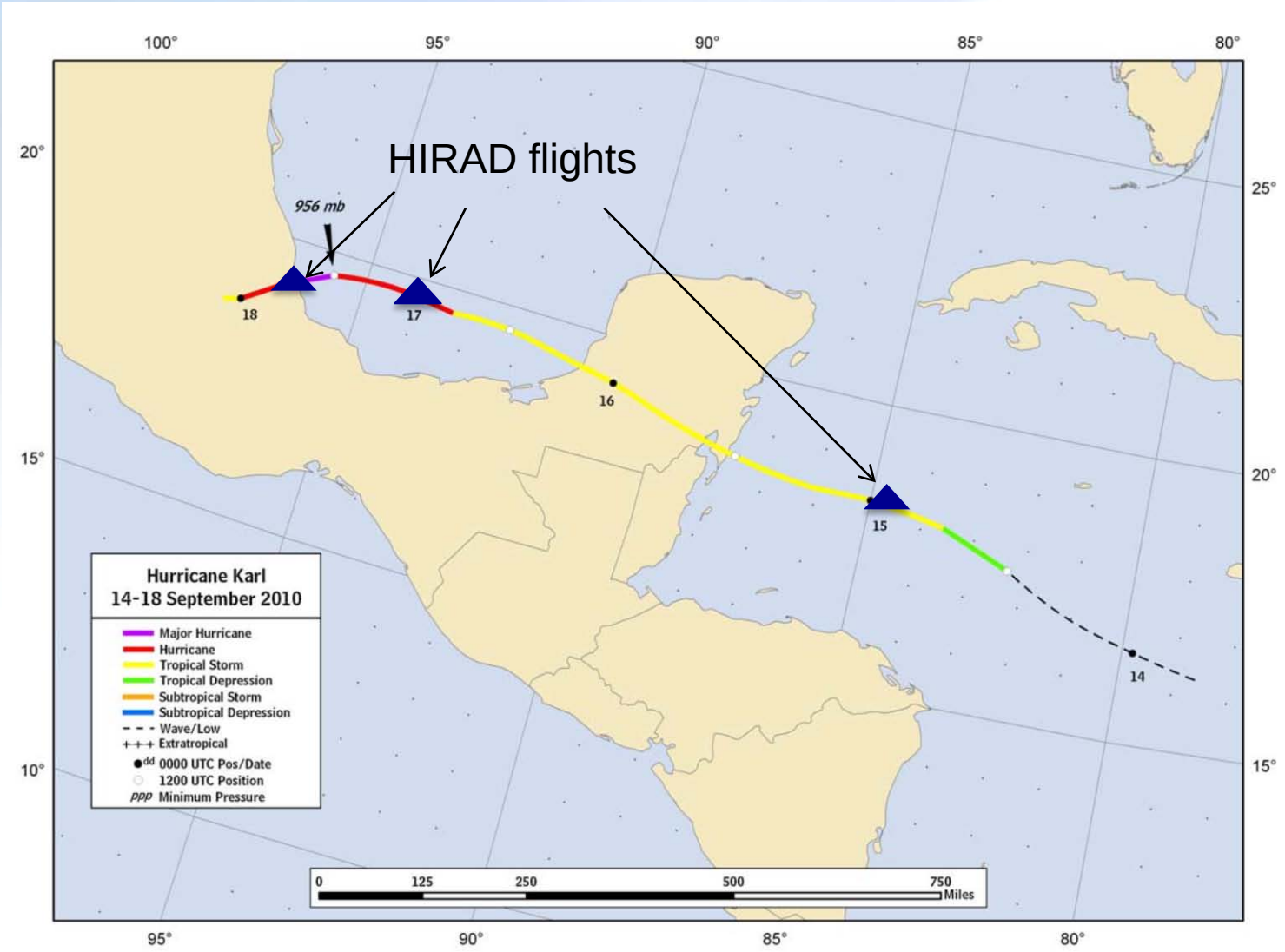
SFMR passes over HIRAD swath

Storm-centric coordinate system

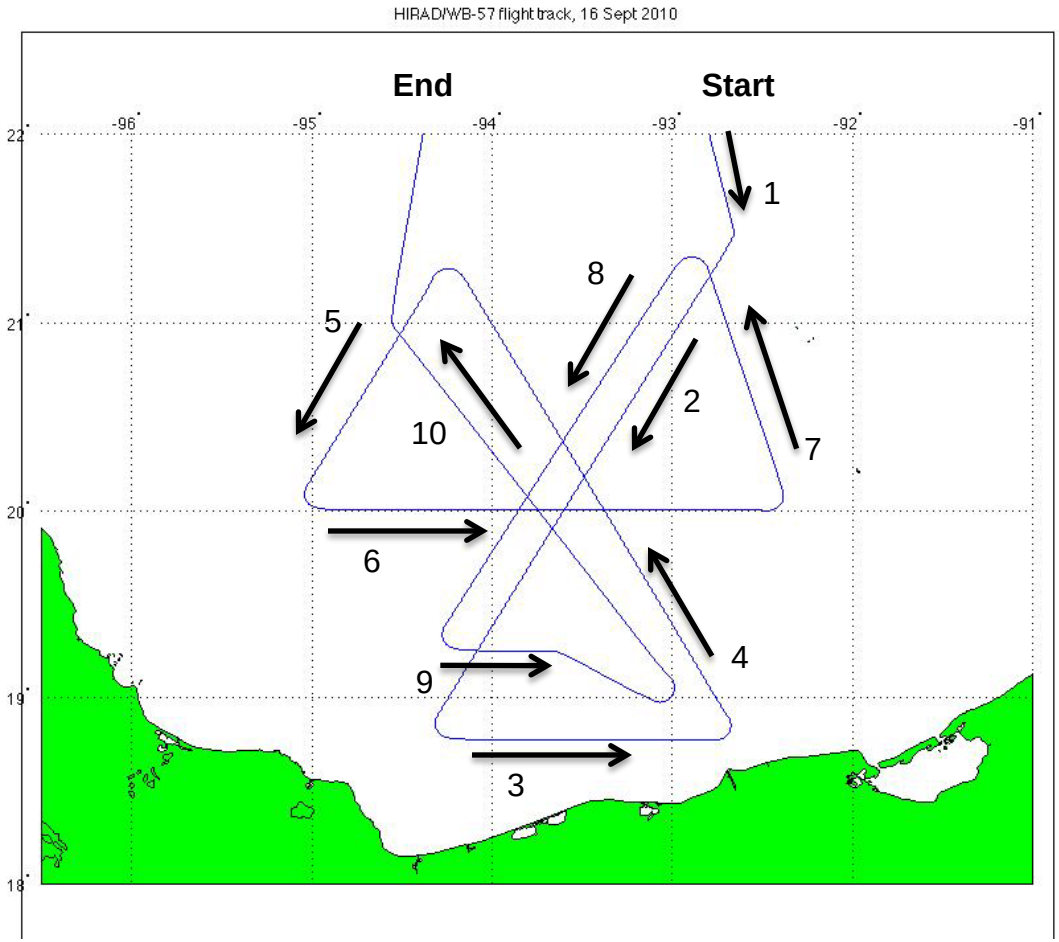


HIRAD and SFMR should match at HIRAD's nadir point

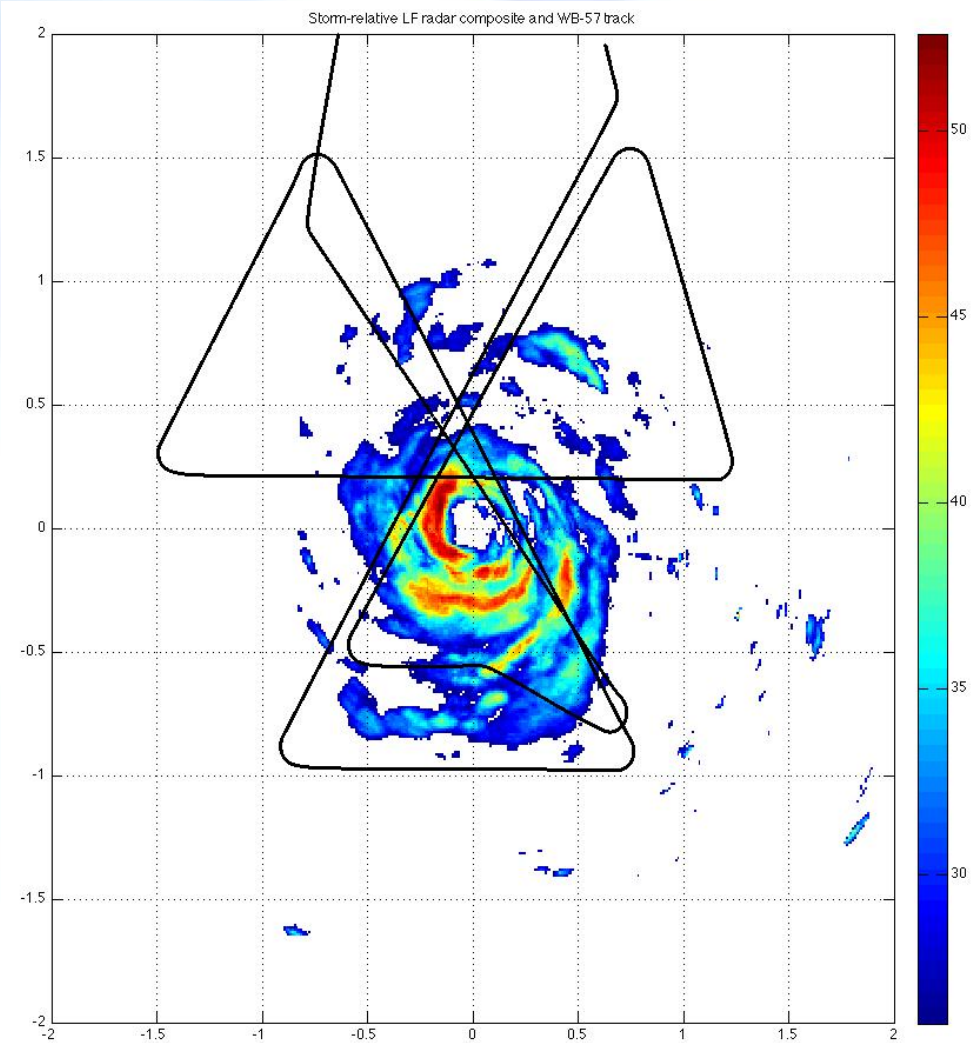
Karl Best Track



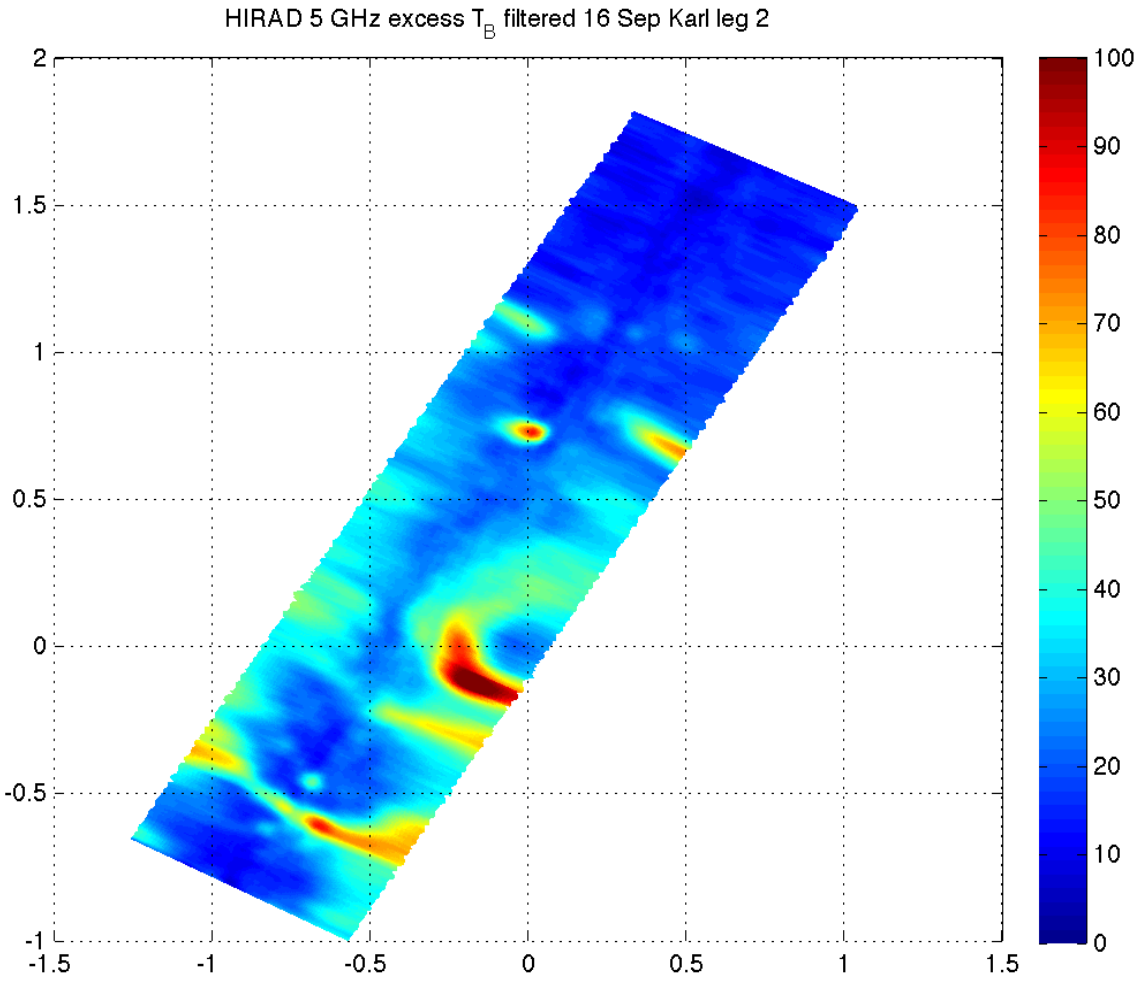
HIRAD / WB-57 flight track and legs definitions, Karl Sept 16



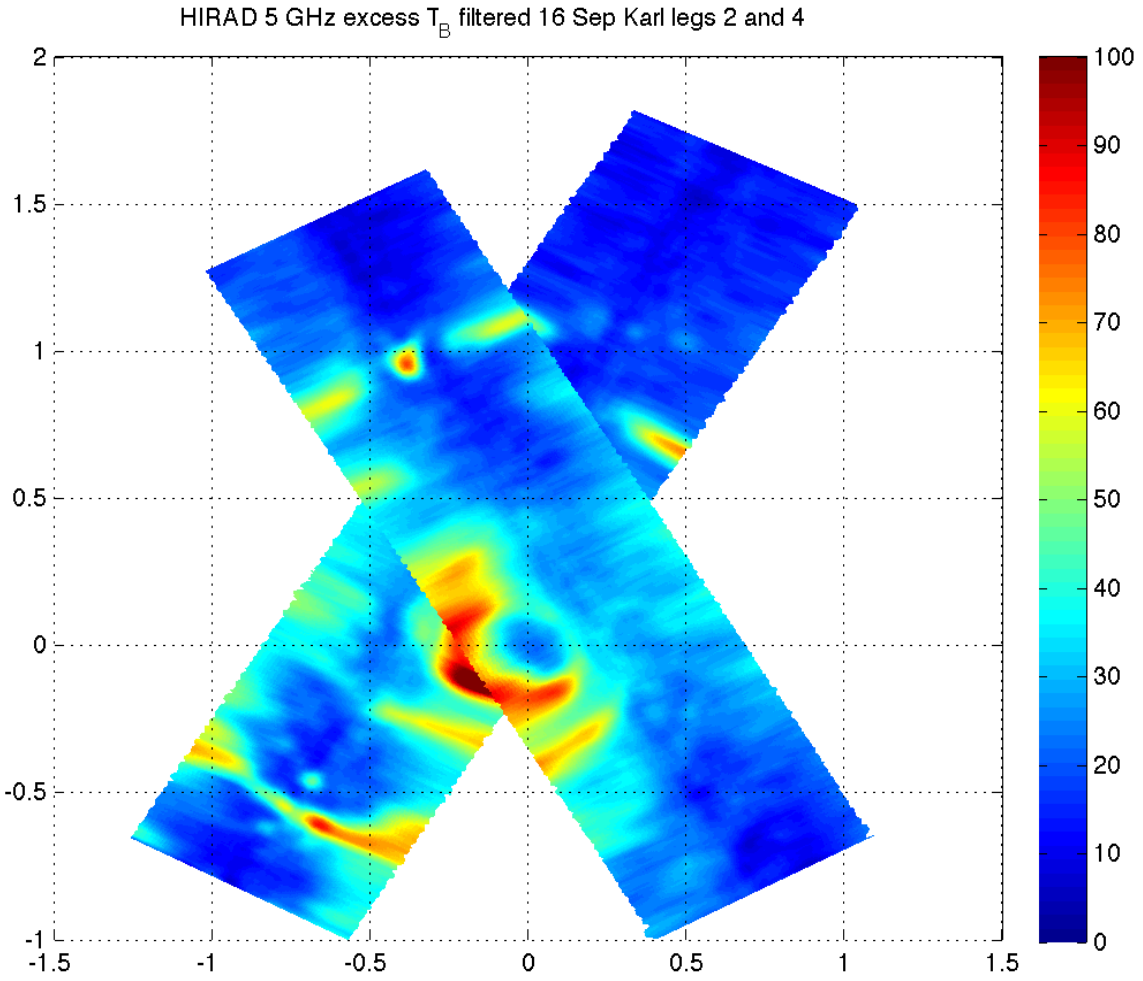
- The storm-relative WB-57 flight track is shown over an image of radar reflectivity from the NOAA P-3.
- The storm center as determined from HIRAD data is used as the plot's origin.
- Note that the radar and HIRAD agree very well on the location of the storm center.
- The following images show agreement on storm structure.



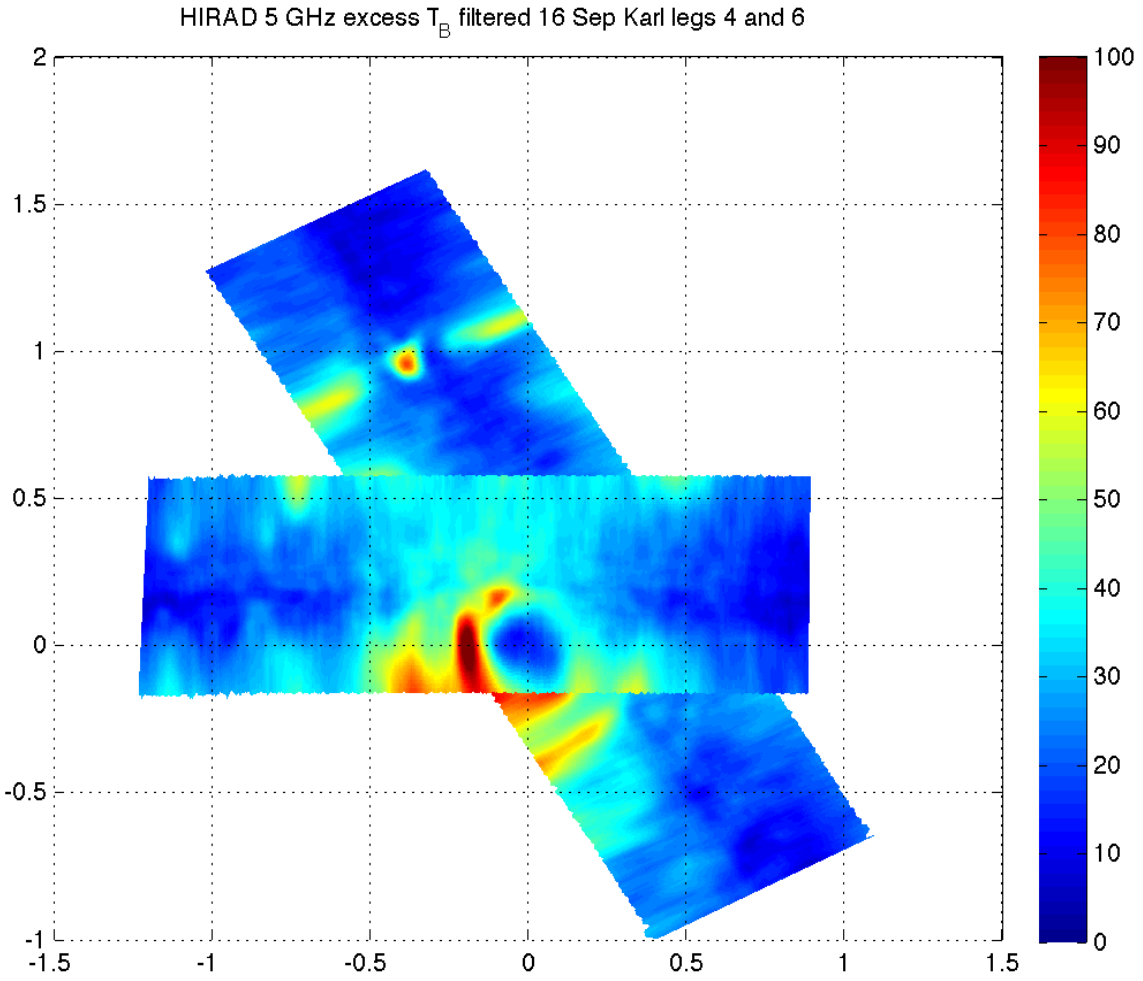
KARL Leg 2


HIRAD 5 GHz excess T_B filtered 16 Sep Karl leg 2
2
1.5
1
0.5
0
-0.5
-1
-1.5
-1
-0.5
0
0.5
1
1.5
100
90
80
70
60
50
40
30
20
10
0

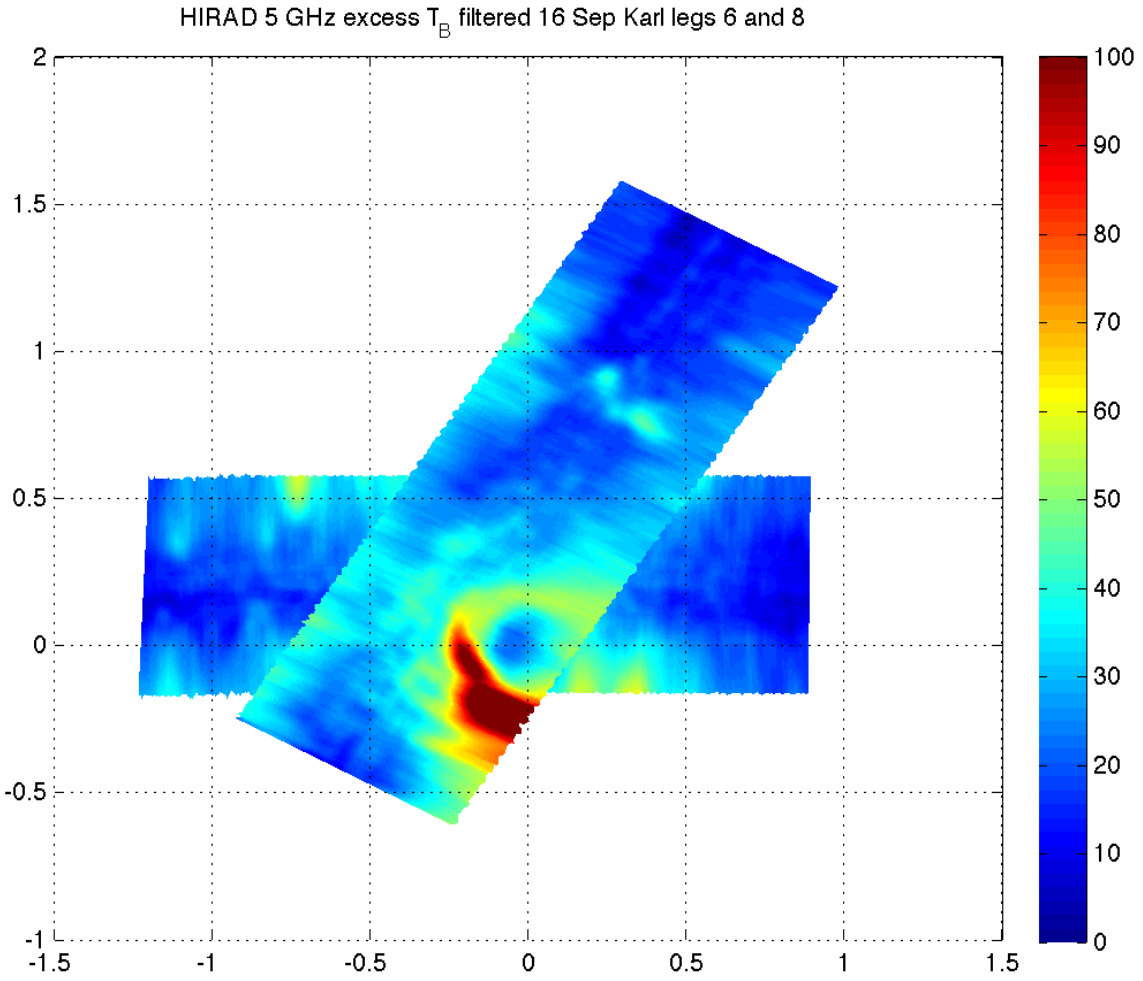
KARL Legs 2,4


HIRAD 5 GHz excess T_B filtered 16 Sep Karl legs 2 and 4
2
1.5
1
0.5
0
-0.5
-1
-1.5
-1
-0.5
0
0.5
1
1.5
100
90
80
70
60
50
40
30
20
10
0

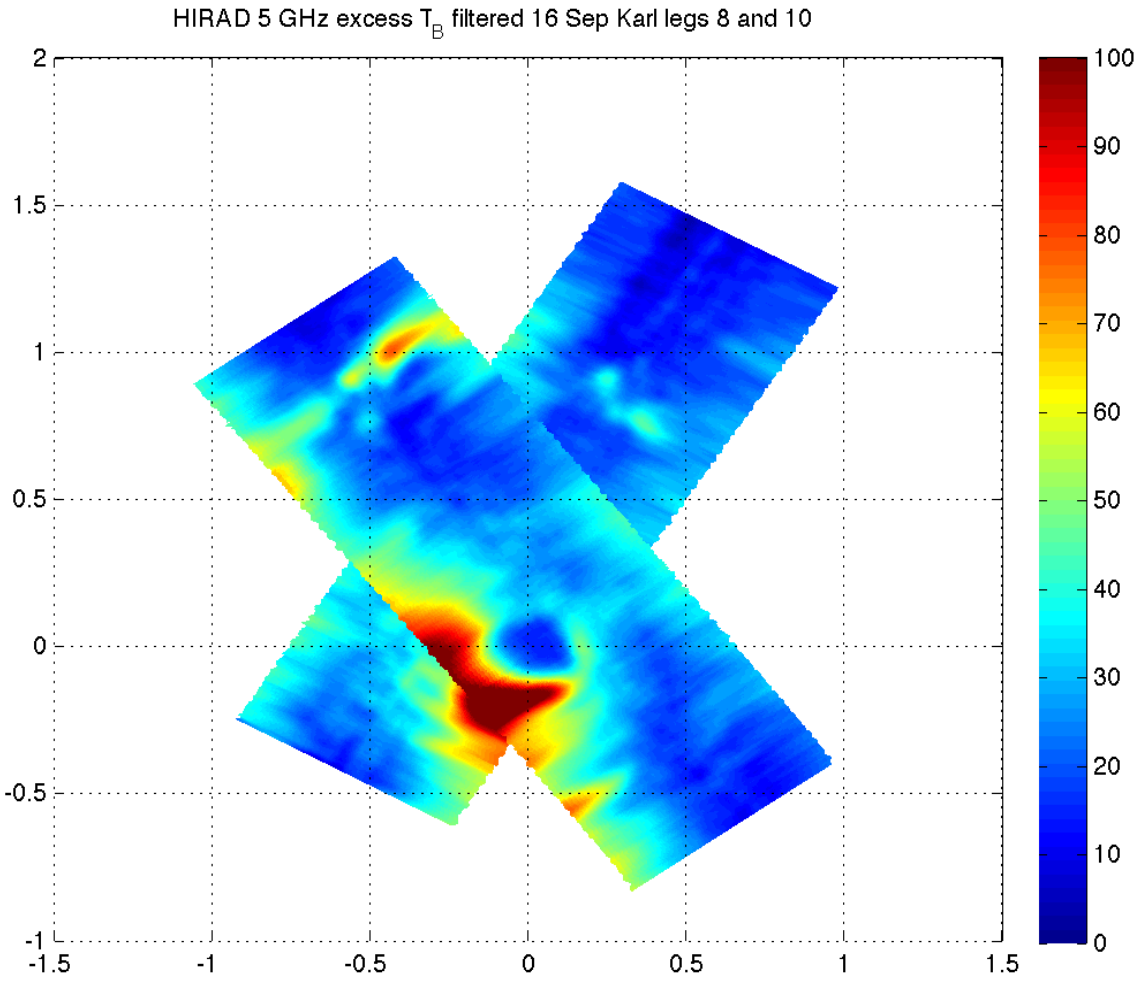
KARL Legs 4,6


HIRAD 5 GHz excess T_B filtered 16 Sep Karl legs 4 and 6
2
1.5
1
0.5
0
-0.5
-1
-1.5
-1
-0.5
0
0.5
1
1.5
100
90
80
70
60
50
40
30
20
10
0

KARL Legs 6,8


HIRAD 5 GHz excess T_B filtered 16 Sep Karl legs 6 and 8
2
1.5
1
0.5
0
-0.5
-1
-1.5
-1
-0.5
0
0.5
1
1.5
100
90
80
70
60
50
40
30
20
10
0

KARL Legs 8,10



HIRAD Calibration Challenges

- To date, only the 5 GHz Tb's have been successfully produced
  - Wind speed and rain rate retrievals await at least one other frequency
- Calibration of HIRAD's many channels/sub-bands and their cross-correlations is a very complex process
- Hardware components are susceptible to changes in ambient temperature (for example)
- Study continues on whether we will need to perform calibration tests in a temperature chamber in order to produce calibrated Tb's at other frequencies and hence retrieve wind speed and rain rate
- We are also determining how to ensure that calibration in future flights (e.g. HS3) will be routine

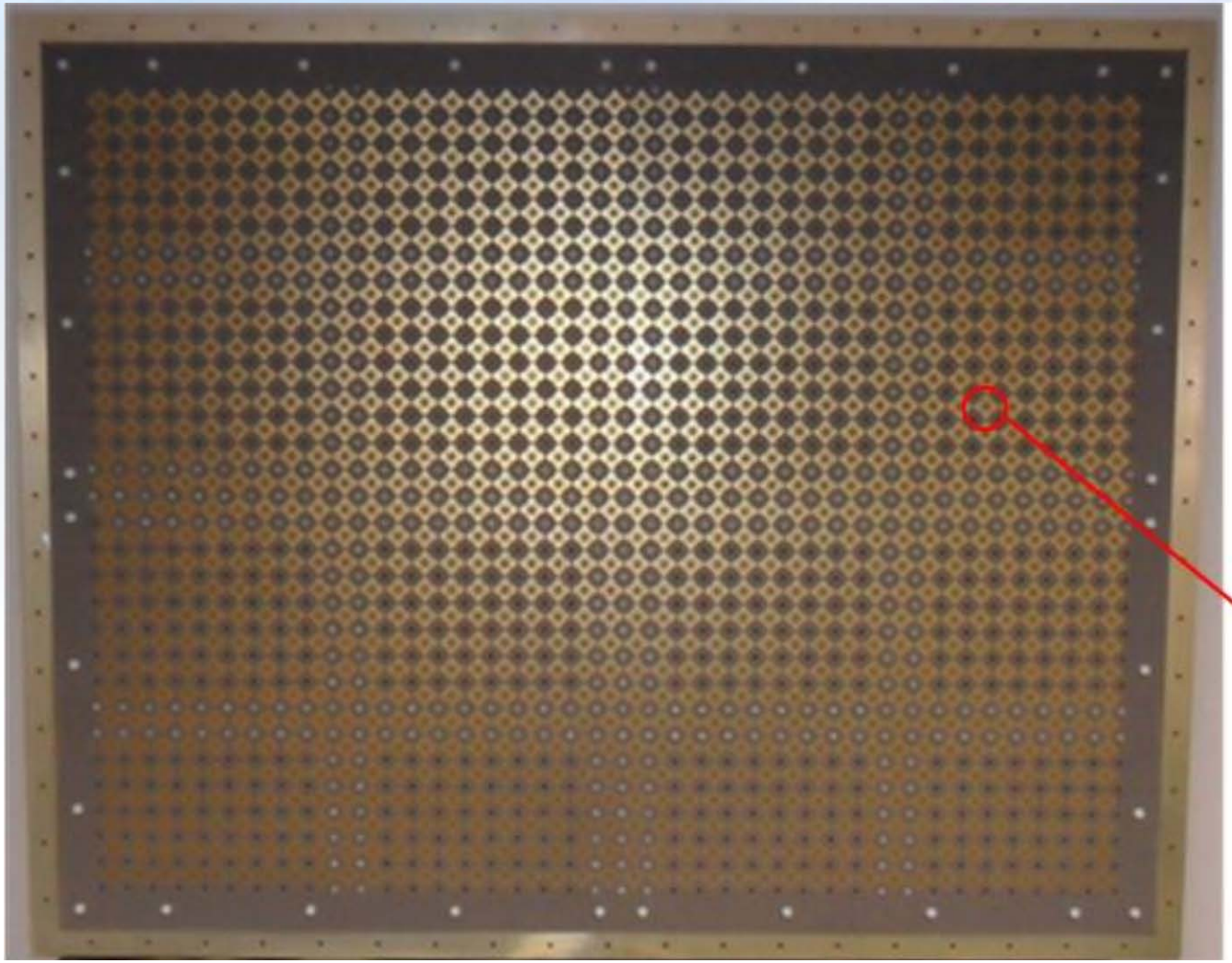
Summary

- HIRAD is a new technology developed by NASA/MSFC, in partnership with NOAA, the Universities of Central Florida, Michigan, and Alabama-Huntsville
- HIRAD measures wind speed and rain rate over the ocean in heavy-rain, strong-wind conditions
- HIRAD is expected to eventually fly routinely on NOAA unmanned aerial vehicles (UAVs) over hurricanes threatening the U.S. coast and other Atlantic basin areas, and possibly in the Pacific as well
- HIRAD first flew on GRIP in 2010 and is planned to fly 2012-14 on the NASA research mission, HS3 (Hurricane and Severe Storm Sentinel) on the Global Hawk, a high-altitude UAV (described in an earlier presentation by Scott Braun)
- HIRAD technology is hoped to eventually be used on a satellite platform to extend the dynamical range of oceanic wind observations from space

Next-generation HIRAD

- A fully polarimetric HIRAD system will add the capabilities:
  - Wind direction, in addition to speed
  - Improved accuracy in wind speed observations, especially at large off-nadir angles
- The first step in developing this system has been accomplished
  - Dual-pol antenna developed via SBIR
  - New design receives and discriminates cross-pol and co-pol radiation
  - Detailed tests to be conducted in spring, summer of 2012
- Rest of system to be proposed in FY13 Instrument Incubator Program announcement of opportunity
  - New system ready for flight test in FY15

New dual-pol antenna



View of single dual polarized balanced output antenna element